SAVONIA

Thesis - BACHELOR´S DEGREE PROGRAMME
TECHNOLOGY, COMMUNICATION, AND TRANSPORT

3D MODEL OF PORTABLE POWER SYSTEM

A hybrid model of solar panels and wind turbine

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SAVONIA UNIVERSITY OF APPLIED SCIENCES THESIS
Abstract

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Abstract

The purpose of this thesis was to design a 3D model for the portable hybrid power system which combines four solar panels with one wind turbine. The hybrid model will be more beneficial in all kinds of seasons. It is easy to transport from one place to another with the help of a trailer. The portable system is useful for outdoor activities and emergencies like floods, earthquakes, and landslides and where electricity is not easily accessible. Once installed, it does not need to be looked after, however, the solar panels need to be cleaned occasionally if used in a dusty place. The main aim of this 3D model is to generate clean and green energy at a low-cost.

To achieve satisfactory results energy resources, product designs, and systems were studied. The model is based on two renewable sources, i.e. solar energy, and wind energy. Solid works 2019 was used to design the model.

This model is portable and would generate electricity by the sun and wind, store it and convert into alternating current. The model is transportable by a trailer. The trailer is 4.25 meters long and 1.85 meters wide in size and it weighs around 1220 kg with its equipment. The trailer has four solar panels, one wind turbine, battery, hybrid charge controller, and inverter. It can easily be towed with the help of a car and can be stabilized with the help of stabilizing stands.

The conclusion of this thesis is to show that renewable sources-based hybrid systems can be portable and can be applied to overcome electricity problems.

Keywords
solar power, wind power, portable hybrid power systems, 3D model

CONTENTS

Abbreviations

GHG	Greenhouse gas
DC	Direct Current
AC	Alternating Current
K. E.	Kinetic Energy
V	volt
PV	Photovoltaic
HAWT	Horizontal-axis wind turbines
VAWT	Vertical-axis wind turbines
HRES	Hybrid Renewable Energy Systems
W	Watt
KW	Kilowatt
KWh	kilowatt-hour

1 INTRODUCTION

All types of energy resources always have a great contribution to human benefits. Either non-renewable sources or renewable sources are used. According to National Geographic, the non-renewable energy sources are those types of sources which will run out one-day, examples include oil, coal, fossil fuels, etc. These non-renewable sources are in a limited amount in the earth which is on the continuous verge of depletion. So, less use can only take care of these resources. On the other hand, the sources have negative impacts on the environment due to a huge quantity of carbon dioxide and other GHG emissions.

An alternative to non-renewable sources is renewable sources so that these sources are also known as alternative resources. Using these resources reduces non-renewable sources´ use. Renewable sources refer to those energy sources that can be re-gain through continuously by recreating or generating from their sources. Solar, wind, hydroelectric energy, biomass, geothermal power, etc. are some examples of renewable sources. Hence, alternative energy sources are getting more attention due to energy crisis and serious environmental pollution caused by the extreme use of non-renewable sources like fossil fuels. Among these non-renewable energy, wind power and solar power are becoming more popular due to low investment, and high economic performance than others (National Geographic, 2020). Many scientists are trying to combine applications of both energy sources for big power plants as well as developing an easily transportable power system for better performance.

The main concept of the thesis is to present the idea of a 3D model of portable hybrid solar and wind power systems that can be transported from one place to another easily. This model combines more than one electricity generating system, i.e. solar panels combined with a wind turbine together, which makes it a better system because solar energy resources have a negative correlation with wind resources. (Dinga et al, 2019). In this model, the standard size of solar panels and a wind turbine are used which are available in the market.

2 RENEWABLE ENERGY RESOURCES

According to National Geographic, renewable energy is also called "green energy" or "clean energy" because this source produces clean energy which means less pollution and no greenhouse gas emissions that contribute to climate change. These sources are available in nature in unlimited amounts and are regenerated in natural processes over a relatively short period of time. These forms of energy can be replaced after every use (Bhatia & Gupta, 2018, p.2).

In recent years, interest in renewable energy has increased because of climate change, growth in carbon dioxide emission from various sources, and health impacts. These resources can not only provide sustainable energy but also can play a important role in the reduction of carbon emissions and GHG gases. That´s why renewable energy is a good choice for humans and the environment. Renewable energy sources include solar power, biomass, wind power, water energy (a hydro-electrical, ocean wave, and tidal energy), and geothermal energy (Bhatia & Gupta, 2018, p.2).

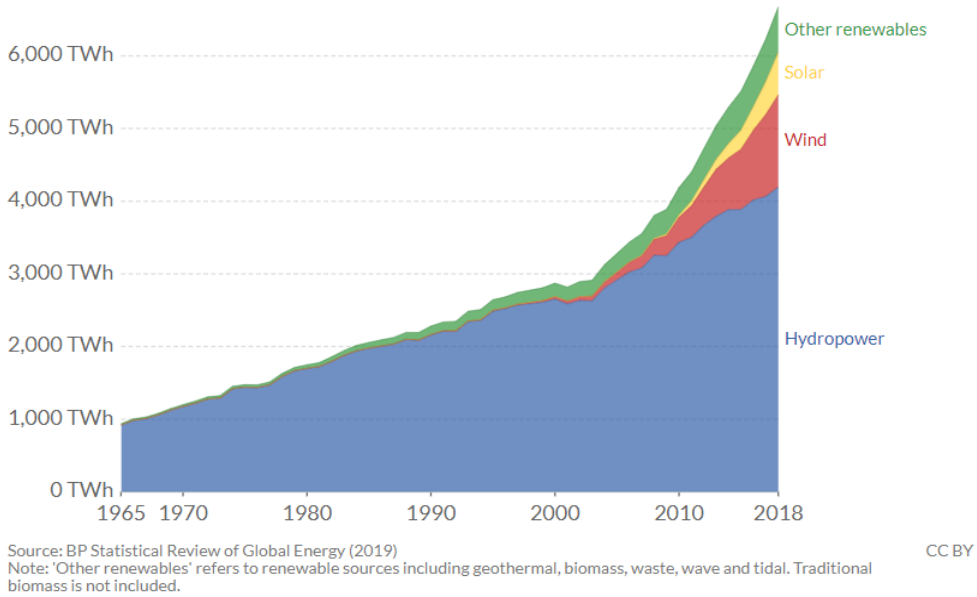

FIGURE 1. A global renewable energy production from 1965 to 2018. (Our World in Data, 2019)

Figure 1 shows the use of renewable energy over 50 years globally and comparison in use between hydropower, wind, solar, and other renewable energy. The value of energy is measured in terawatt-hours per year. According to the chart, hydro energy remains the dominant form of renewable energy consumption than other renewable resources, but hydropower use is slowly declining as other renewable technologies grown up. However, the model being developed for the thesis is based on solar and wind renewable sources.

2.1 Solar power

The sun is the oldest natural resource for heat and light. Radiation of the sun can produce light, heat, causes chemical reactions, and electricity generation (Ashok, 2020). Light and heat are the best during the day hours of summer. There are a lot of technologies used to convert solar power and light into electricity, heat production, and cooling systems for businesses and industrial use. According to Yellow Lite (Harvesting Clean Energy), there are two methods of converting solar energy to electricity, i.e. active and passive. Passive solar energy harnessing is the technique that uses large windows facing south, allowing the sun to warm up heat-absorbent material inside, which releases heat during the night. This effect is used more efficiently with heat collection that absorbs heat from the sun to warm liquid running in tubes to supply hot water. An active heat collection would be heating tubes filled with oil. The hot oil then boils water, and then the resulting steam used for electricity generation.

There are a seven most common solar energy uses (Freedom solar power,2018).

Solar Electricity	Electricity can produce through the solar panels
Solar Water Heating System	Solar water heaters used to heat the water tank by the heat of the sun through a rooftop cell.
Solar Heating	Solar heating systems for heating the house.
Solar Ventilation	Solar attic fans for cooling the house during the summer.
Solar Lights	Security light produces for streetlights and road signs.
Portable Solar	Portable solar PV chargers for phones and tablets or other personal electronic devices.
Solar Transportation	Solar-powered vehicles are run through sun energy such as buses, trains, airplanes, cars, and racing cars.

Solar energy was chosen as one of the sources for this project, since it is relatively easily available almost everywhere, and does not require any fuel or raw material. Photovoltaic panels can generate electricity and store them in batteries when the sun shines**.** Hydropower and Geothermal plants cannot be moved since their source of power generation cannot be accessed elsewhere. Likewise, a biogas plant is difficult to move around due to many phases and containers and a constant need for raw material.

2.2 Wind power

According to National Geographic, the wind is a outcome of the uneven heating and cooling of the environment by the sun. Radiation of the sun heats air masses and changes air pressure which causes air masses to move under the effect of a pressure difference. It is also a non-polluting natural renewable energy source that does not need other fuel or usage costs and is freely available everywhere. The energy production from wind energy is due to kinetic energy that is converted into usable energy like mechanical energy or electrical energy. The wind turbine can capture kinetic energy generated from the flow of wind and converted into mechanical energy and mechanical energy converts into electricity through a generator. It does not need fuel or raw materials. Wind energy used to move water-pump, grind crops into flour, ships, and to generate electricity. The air movement harnessed turbines to generate electricity.

The wind is considered an unreliable resource of energy since the availability of wind cannot be guaranteed all the time to produce electricity. Moreover, many factors affect the speed and strength of the wind such as a geographical situation, the presence of mountains, vegetation, and bodies of water can affect the wind flow patterns. Storing the energy in batteries is an effective way for direct use, wherein large-scale a battery huge capacity would be required.

Usually, three types of wind energy are present according to place and their capacity (American Wind Energy Association, 2020).

i. Utility-scale wind
   It is also known as the large-scale wind. It is based on capturing energy greater than one megawatt (MW). In this case, turbines´ size range is from a hundred kilowatts to several megawatts.

ii. Small wind or distributed wind
   It includes single small wind turbines below a hundred kilowatts. Turbines are not connected to the grid.

iii. An offshore wind
   The wind force that produces around the sea. The land-based turbines are smaller than these wind turbines. The offshore wind can produce more energy.

3 DESCRIPTION OF HYBRID SOLAR-WIND POWER SYSTEM

An energy system that combined different energy sources to get more energy is called the hybrid energy system. It has better performance, stability, reliability, environmental-friendly, and economical. (Ingole et al, 2015 p.1). However, in this model being designed, two renewable energy sources are used for generating electricity. They are a solar power system and wind power system. These renewable energy sources are better than any other non-conventional energy sources. They are available in all areas directly or indirectly so that there is no need to arrange a special site for installation. (Ingole et al, 2015 p.1.) Solar panels and wind turbine generate electricity power when their respective energy source is available.

The solar-wind power system uses the batteries for storing the energy via controllers. Storing energy is helpful during the absence of source energy and improves system reliability (Chandramouly & Raghuram, 2017 p.4).

3.1 The combined structure of solar power and the wind power system

The hybrid power system is the concept of generating and utilizing electrical energy production from the sun and the wind. The model includes solar panels and wind turbines with their power conditioning units like charge controller, batteries, and inverter. Figure 2 describes the generation structure of the hybrid system.

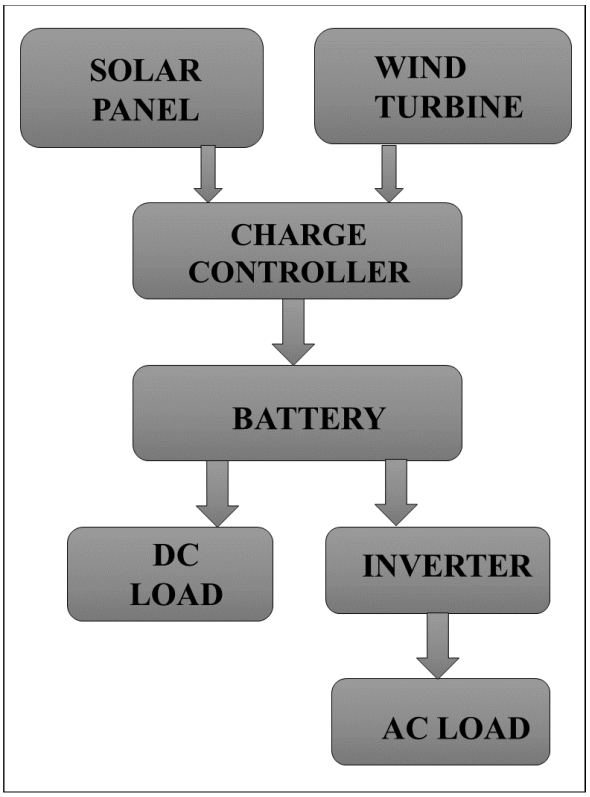

FIGURE 2. The structure of the solar-wind hybrid system (Sonawane et al, 2017 p.169)

Two sets of energy generating systems; solar panels convert solar energy into mechanical energy and a wind turbine that converts wind energy into mechanical energy and then into electric energy. The energy collected from solar panels is in DC form and stored in the battery. The controller supplies power for AC or DC loads. Electric energy generated from wind turbines is alternate and unstable. Charge controlling or inverters used for continuous supply or storing in the battery (Wagh & Walke, 2017). The model has three major functions i.e. energy generation, energy storage, and energy conversion.

There are some benefits as well as limitations of hybrid solar-wind power systems are as follows (Renewable-Solar Energy, 2020).

Advantages

- A hybrid system is considered a well-balanced solution during any cycle because when the sun is strong, the wind tends weakly and vice-versa.
- A hybrid power system is easy for installation and less costly for maintenance.
- All collected energy stored in batteries can give electricity even during the night when it is possible to generate electricity enough.

Disadvantages

- Initially, the project needs a higher investment than a single power system.
- All types of wind turbines are not useful due to wind speed varying with regions and noise.

3.2 The main system components

The portable hybrid solar-wind power system made of solar panels, wind turbines, controllers, batteries, and an inverter. They joined to create a complete energy generation electric system.

3.2.1 The solar panel and its working Principle

A Solar panel is also known as a PV panel or a photovoltaic panel. Solar panels produce DC electricity by absorbing sunlight with photovoltaic cells and convert the sunlight into electricity energy (Britannica, 2020). These photovoltaic panels´ cells are consisted from semiconductor materials, and when radiation from the sun hits these cells, the materials release electrons from their atoms (Adejumobi et al, 2011, p.131). One of these cells can generate around two watts. These cells are connected to form a panel. Small PV panels used in calculators or watches, but solar plants can produce hundreds or thousands of kilowatts through large arrays (Britannica, 2020). The electricity collected from solar panels used to load or stored in a battery (Adejumobi et al, 2011, p.131).

Based on features, solar panels are classified into three types (Energy-sage, 2020).

i. Monocrystalline solar panel

Monocrystalline solar panel is made up of pure cylindrical silicon wafers. These solar panel has better features than other types of solar panels. The circular wafers are octagonal to use the cells. The solar cells are black but have sheets and frames in various colors. The back sheet is often black, silver, or white, while the metal frames are in black or silver color.

The advantages and disadvantages are as follows (India times, 2020).

Advantages

- The cells are in a pyramid pattern with a larger surface for energy collection from the sun´s rays.
- The panels have a long lifetime of up to 30 years.
- The panels have better performance even in a low sunlight.

Disadvantages

- These types of panels are expensive than other panels.
- A lot of silicon waste is produced because of thin wafers produce through silicon block cuts according to the width and vibration of mechanical sawing wire.

The octagonal solar cells are visualized in Figure 3 to get an idea of the monocrystalline solar panel.

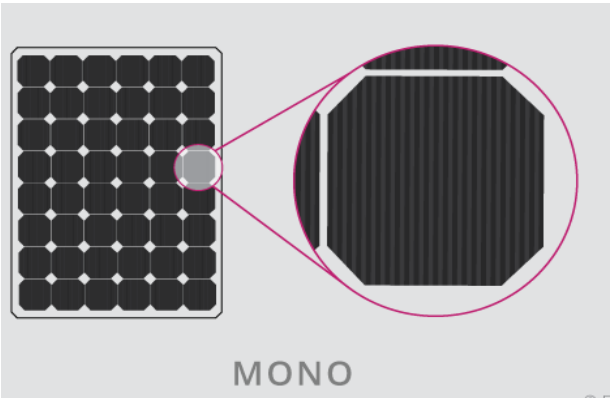

FIGURE 3. The structure of the monocrystalline solar panel (Energy-sage,2020)

ii. Polycrystalline solar panel

A polycrystalline solar panel is called multi-crystalline and is prepared from polycrystals. The polycrystalline solar panels made from silicon materials through the process of molten silicon put into a cast and cooled with a seed crystal. Cells are perfectly square (Solarquotes,2020).

Advantages

- These panels are cheapest among other types of panels.
- Solar panels 'production is easier.

Disadvantages

- Less efficiency and performance than the monocrystalline solar panels.
- These have less life span than the monocrystalline solar panels.

A Polycrystalline solar cell is different in size than the monocrystalline solar cell (Figure 4).

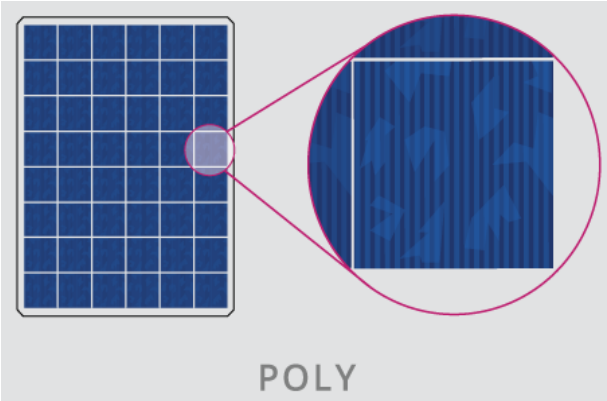

FIGURE 4. The structure of the polycrystalline solar panel (Energy-sage,2020)

iii. Thin-film solar panel

The solar panels are made up of cadmium telluride (CdTe) or amorphous silicon (a-Si) is known as the thin-film solar panel. Though these solar panels use silicon in the composition.

Advantages

- The panels are portable and flexible because of its weight.
- The lower cost of installation than the other two types of panels,

Disadvantages

- The panels have low performance and power capacities.
- The panels have a short life with a shorter warranty.

The structure of the thin-film solar panel is quite look-alike monocrystalline, but it is different due to its composition (Figure 5).

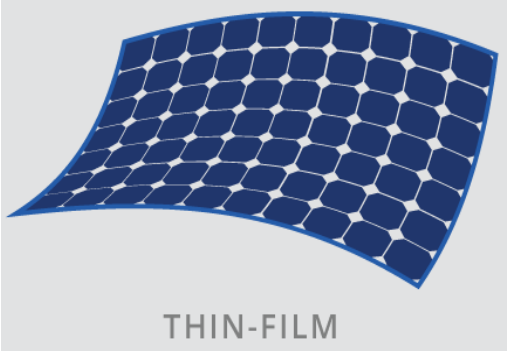

FIGURE 5. The structure of a thin-film solar panel (Energy-sage, 2020)

The formula for the energy output from a solar panel (Vivint Solar,2020).

The solar panel (watts) x sunlight hours x 75% = daily watt-hours

Where 75% considers all variables such as dirty modules, dirty air, high humidity, hot modules, wiring losses, small bits of shading, inverter inefficiency, and all other little things affect efficiency. If off-grid systems used, then 70% assumed or 80% for perfectly shading-free, dry, and high altitudes.

3.2.2 Wind turbine and its working Principle

Wind turbines are used for absorption and conversion of energy. There are two parts of system, i.e. the wind turbine and a generator. The energy produced by the wind is converted into mechanical energy by wind turbine and that energy is further converted into electrical energy by using generator (Roux et al, 2010, p. 9).

Types of Wind Turbines

Wind turbines are categorized into two based on how they rotate i.e. vertical axis wind turbines (VAWT) and horizontal-axis turbines (HAWT). Both wind turbines include the same basic components. They are a base, a tower, generator, gearbox, yaw motor, a rotor, a control system, and a transformer (Roux et al, 2010, p. 11-14).

a) Horizontal-axis wind turbines

HAWT rotates the rotor blades parallel to the ground. The generators and rotors lie at the top of a tower and pointed towards the wind (Figure 6).

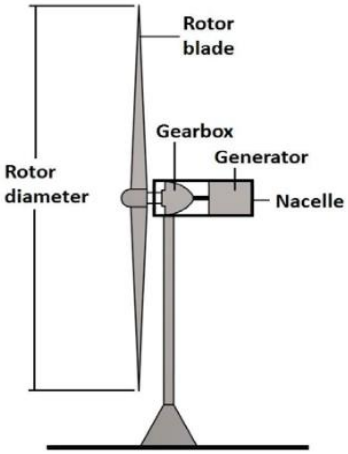

FIGURE 6. A horizontal-axis wind turbine and its principal components (Roux et al, 2010, p. 9)

b) Vertical - axis wind turbines

VAWT has a vertical rotor shaft. The main components are placed near to the ground that makes easier for repairing and servicing. The turbines are divided into two groups.

Drag-based
Wind power extracted through aerodynamic drag.

Lift based
The blade is perpendicular to the wind force.

Here, Figure 7 shows the vertical- axis wind turbine and its components.

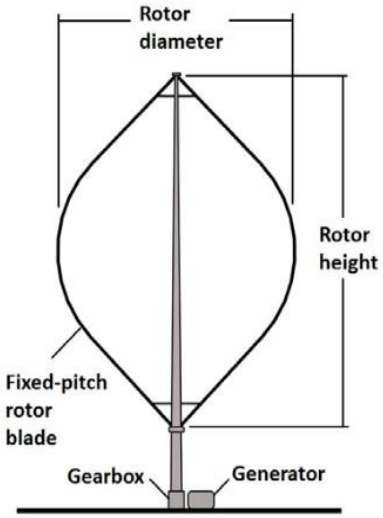

FIGURE 7. A vertical- axis wind turbine and its principal components (Roux et al, 2010, p. 10).

Types of VAWT

According to aerodynamic and mechanical characteristics, there are two types of VAWT. They are (Roux et al, 2010, p. 10).

I. The Savonius

The savonius wind turbines designed on drag based. Usually, boats contain this type of turbine for operation. In this turbine, vertical S-shaped surface blades rotate around a central axis (Figure 8).

Advantages

- High torque
- Easy to build, small, design
- Easy maintenance
- Function well in low wind speed

Disadvantages

- Low rotation speed than a lift-based
- Less power generation
- Considered as unsuitable for electricity production

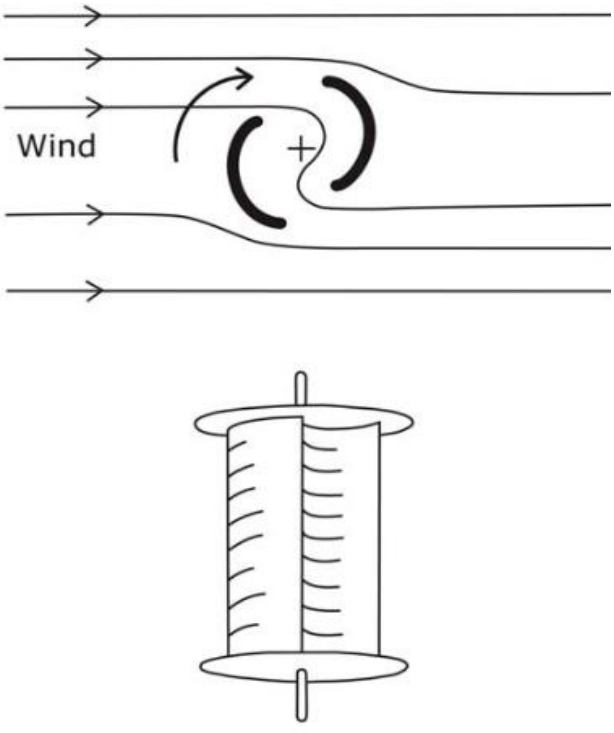

FIGURE 8. A top view of wind flows across blades (above) and a savonius rotor (below) (Roux et al, 2010, p. 13).

II. The Darrieus

Darrieus turbines are designed on lift-based turbines and work on aerodynamic principles. A typical wind turbine is shaped on a C-shaped rotor (Figure 9). It usually contains two to three blades. Again, it is split into three categories. They are D - Darrieus, H – Darrieus, and helix Darrieus (Roux et al, 2010, p. 12).

Advantages

- It has a high rotational speed
- Cheaper to produce
- Easy to transport
- Able to good function in extreme weather because the rotor can take the wind from all direction

Disadvantages

- Wind turbines with a low starting torque
- Small effective operating range

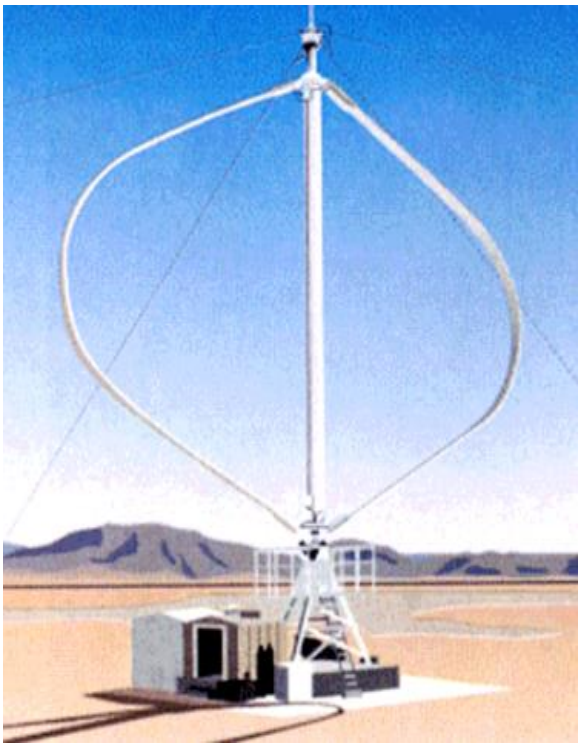

FIGURE 9. A darrieus wind turbine (Roux et al, 2010, p. 13).

H- darrieus VHWT is also known as a darrieus turbine but its blade is in H shape (Figure 10). The blades of a wind turbine can be in different numbers which can be five, four, or two blades.

Figure 10. H- darrieus VHWT (RexCo Technology, 2020)

According to the aerodynamic principles of a wind turbine, mechanical power output can be figured out using the following formula (Chandramouly & Raghuram, 2017, p.3).

$$P_{avail} = \frac{1}{2}\rho A v^3 C_p$$

In the formula,

P = power (W)

ρ = air density (Kg/m^3)

A = swept area (m2)

V = wind speed (m/s)

C_p = wind power coefficient

The following equation helps to calculate the sweat area.

$$A = \pi r^2$$

Where,

r = radius equal to the length of the blade

For the H - Darrieus VAWT, the sweat is given by,

$$A = d * h$$

Where,

d = diameter of the rotor (m)

h = length of the blades (m)

Figure 11 helps to understand the diameter of the rotor and the height of the blades in H-darrieus VHWT.

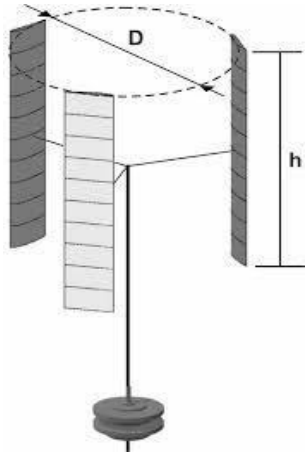

FIGURE 11. a swept area of vertical axis wind turbine (Fadil et al, 2017)

The value coefficient Cp is known as an energy amount that a exact turbine can consume from the wind. The Cp value concerned with a wind turbine type and a value of an index ƛ, that called a tip speed ratio and expressed by (Ragunath et al, 2016, p.306).

$$ƛ = \frac{\omega \times r}{v}$$

here,

ω = the turbine rotational speed (rpm)

r = the radius of the rotor (m)

v = undisturbed wind speed (m/s)

Betz law states that," all wind turbine can convert only 16/27 (59.3%) of kinetic energy into mechanical by turning a rotor. The efficiency of any wind turbine is 59% which is also known as power coefficient.

$$c_{Pmax} = 0.59$$

C_P value is different for individual turbine type and is a wind speed function.

Therefore, VAWT is used because it is most suitable for generating electricity for homes and charging for batteries. It does not need to be pointed towards the wind for effectiveness, thereby the need for a yaw drive mechanism. The design of the blades is simple, they can have constant chords and no twist. It also has a few disadvantages. Wind variation may apply in each rotation of the sensitive blades of the wind turbine when it is installed in unfavorable condition (Roux et al, 2010, p. 13).

3.2.3 Cable

The right size of wires needs to be chosen in the electrical circuit for safety and performance. The undersized wire can cause voltage drop resulting in excess power loss. Likewise, it heats-up wires that may result in fire. The current carrier electric wires can be compared with a water carrier hose. The shorter diameter hose has a better flow than a larger hose. The electric wires act as same as a hose. The wire must be the constant and small length as possible when it connects the batteries which keep up the longer-life of the battery. It also helps to decrease voltage loss. The least voltage drop in the system is 2% to 3% (Windynation, 2010).

The voltage drops can be calculated by the following formula (12 Volt Planet Ltd. 2020).

Voltage drop (V_{drop}) = I x R

Where,
I = current
R = resistance

A select a supply voltage (V)	= 12 V
The current in amps	= 200 amps
Cable size in mm^2	= 10
Cable length in m	= 0.5
Drop in volts	= 0.34
Drop as a % of the supply voltage is	= 2.83

Generally, an acceptable maximum voltage drop percentage is around 3 to 4% (12-volt planet, 2020).

3.2.4 Charge controller

The hybrid solar and wind energy system assures continuous power supply all through the day and night. Different power energy is coming from both solar panels and wind turbines at various periods.

The charge controller simply blocks reverse current and prevents battery overcharging (Durgam et al, 2015, p.8). There are many brands, models based on their output, size, capacity, and other factors.

3.2.5 Battery

Energy generated from portable hybrid solar-wind power systems must be stored in some device because neither sun nor wind can be a 100-percentage effective energy provider over a year. The battery is run by an electrochemical reaction. The collected energy is stored in the device called a battery which can supply electricity in peak demand. The battery size may depend upon the load and output of the system. When there is more than one battery, batteries connected in parallel or series connection to increase capacity (The Walden Effect, 2012).

A calculation of watts the battery can hold (The Walden Effect, 2012).

Battery in watt-hours = Volts X Amp-hours

It assumed that only 60% of energy is used in a battery.

Usable amount in watt-hours = 0.6 X Battery watt-hours

3.2.6 Inverter

An inverter is an electronic device required to convert direct current into alternative current by its turn on and off a semiconductor power switching device. The device does not produce electricity itself. The solar panel can produce DC and have a power supply with the greatest current and voltage for a given illumination condition where a wind turbine can produce AC with the most efficient production varies with the speed of the wind. Based on its composition, the inverter is categorized into two types. They are a modified sine wave and pure sine wave generators (Doucer et al, 2006-7).

In a modified sine wave inverter, the production of the waveform is easy because of a simpler process and switches from positive to negative. It is less expensive. Some appliances such as microwaves, refrigerators, and compressors that have AC motors won´t run as efficiently as they would on a pure sine wave (Doucer et al, 2006-7).

Pure sine wave inverter is costly than a modified sine wave inverter because of its added circuitry. That is good for providing energy to all AC based electronic applicants allowing inductive loads to run faster and noiseless (Doucer et al, 2006-7).

In hybrid solar-wind power systems, DC power collected in batteries needed to convert into AC power for use.

4 3D DESIGN OF PORTABLE SOLAR-WIND DESIGN

For the model, the solar panels and a vertical wind turbine kept simple. The main parts of the system designed for the model.

4.1 Solar Panel

In applications, the output characteristics of solar cells are very important to the design system. All types of solar panels have their benefits as well as drawbacks. The project is focused on the design of a portable power system so that the monocrystalline solar panels are better than others. The monocrystalline solar panels have good efficiency with high performance and limited space. The chosen solar panels are accessible in different sizes and watts which are dependent upon the number of solar cells.

The four solar panels are attached a series and can rotate 360^0 horizontal and bends 90^0 vertically. This is mainly because the more solar panels would not fit in the trailer. It is attached to the trailer through the base of solar. Each solar panel is 500 watts which are available in the market.

The specific technical parameters of one 500-watts 96 cells monocrystalline solar panel (GreensubSolar,2020).

Net weight	26 kg
Dimension (L x W x H) (mm)	1960 x 1310 x 45
Number of cells per modules	96

500-watts 96 cells monocrystalline solar panels were a simple 3D model that is easily available in the market (Figure 12).

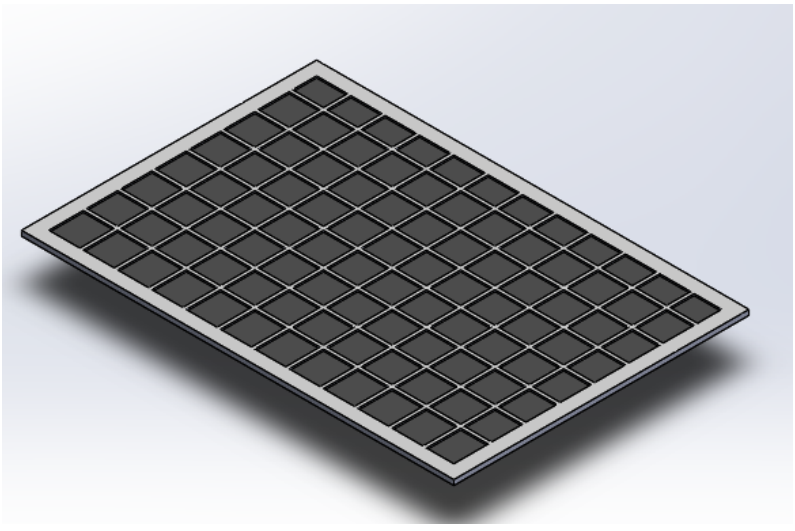

Figure 12. 3D model of solar panel

4.2 Wind turbine

H - Darrieus wind turbine is used in hybrid power system. It is a better designed Darrieus rotor with better efficiency. This is the best option due to easy manufacture, self-controlling through a stall or pitch controller. The components include the rotor, that helps to convert wind energy into mechanical energy. The rotational speed of the rotor shaft is adjusted, by tower supporting the motor and gearbox for a generator which generates electrical energy converting mechanical energy. If the bridge rectifier is used for a wind turbine, it helps to convert AC to DC. (Electronics notes, 2020). DC energy stored in the battery.

The specific technical parameters of 1KW – VHWT is given as follows (Aeolos wind turbine, 2020).

Net weight	28 kg
Height of rotor (m)	2.8
Diameter of a rotor (m)	2
Number of blades	3

3D model of H- darrieus vertical wind turbine which has 3 blades for an optimum power generation. (Figure 13).

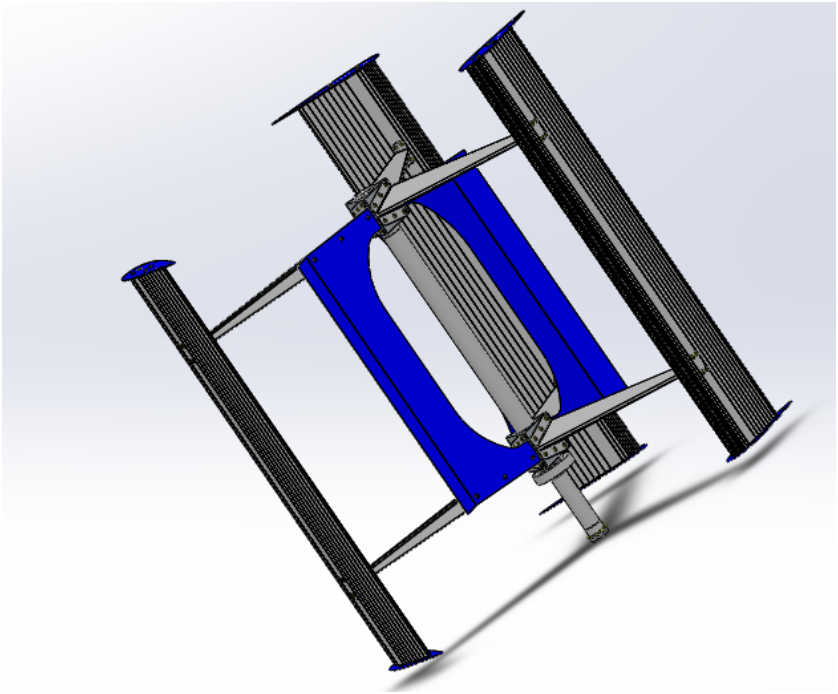

Figure 13. A 3D model of a vertical wind turbine

4.3 Charging controller

The hybrid charging controller helps to control the energy flow from a wind turbine and solar panels before sending it into the battery. Also, it helps to check the overcharging of the

battery. For the model, calculating the formula for the required amperes of a charge controller can (Adejumobi et al, 2011, p.137).

2000W solar power supply (P) = I x V

Here,

I = the expected charging current

V = the voltage of the battery and V = 12V

P = the power supply rating

Therefore, $I = \frac{P}{V} = \frac{2000}{12} = 166{,}67 Amps$

Hence, the value 166,67*Amps* charging controller is not available in the market so that 440 *Amps* charging controller is used (MWands, 2020).

A hybrid charge controller was designed in SolidWorks 2019 with length 30.76cm, width 30.4cm, and 9.88cm (Figure 14).

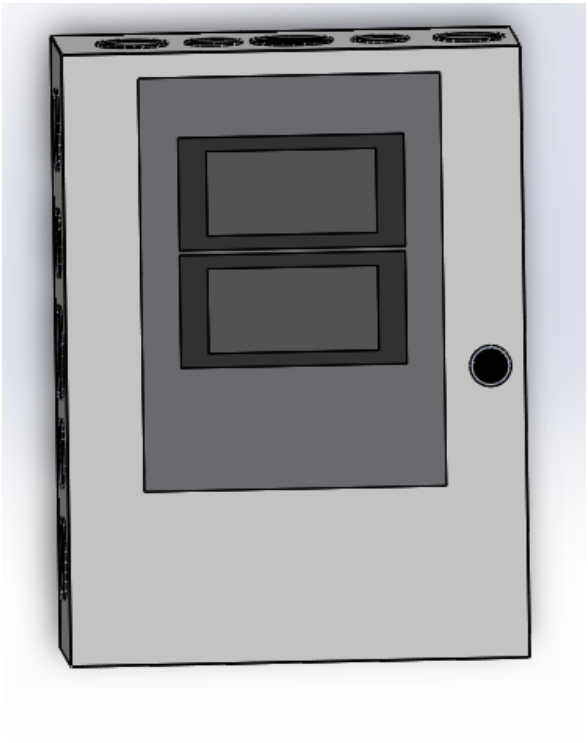

FIGURE 14. 3D model of a hybrid charge controller

4.4 Battery

For the model, the 12-volt 6 cells AGM battery is used. This battery has less than a 2% self-discharge rate per month at 25 degrees Celsius. The capacity affected by the temperature is that at 25 degrees Celsius it works 100% efficiency and at -15 degrees Celsius 65% efficiency.

A constant current discharge from each cell of the battery at a 10-hour rate is 16.2 (Rolls battery engineering, 2020). The four batteries were placed beside the wind turbine in parallel.

The specific technical parameters of the battery is given as follows (Rolls battery engineering, 2020).

Net weight	55.5 kg
Length (cm)	52.2
Width (cm)	20.9
Height (cm)	22.4

The battery was also designed in SolidWorks 2019 to make sure it can perfectly fit in the trailer (Figure 15).

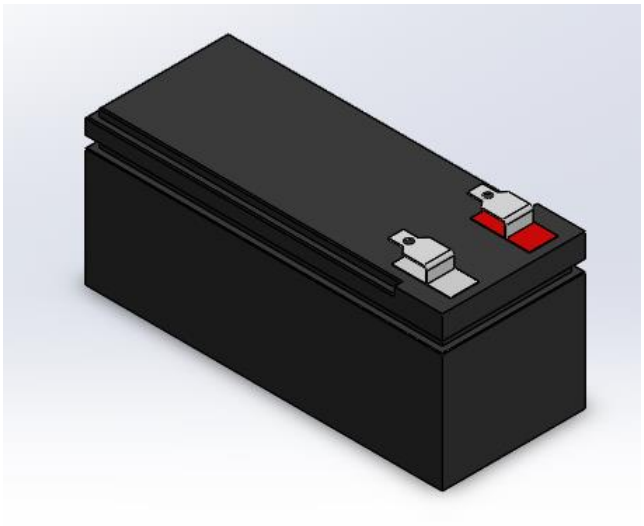

Figure 15. A 3D model of a battery for trailer

The line graph illustrated that the cycle life of the battery increased significantly with the depth of discharge. Also, the rate of discharge increases by the time in hours. (Figure 16).

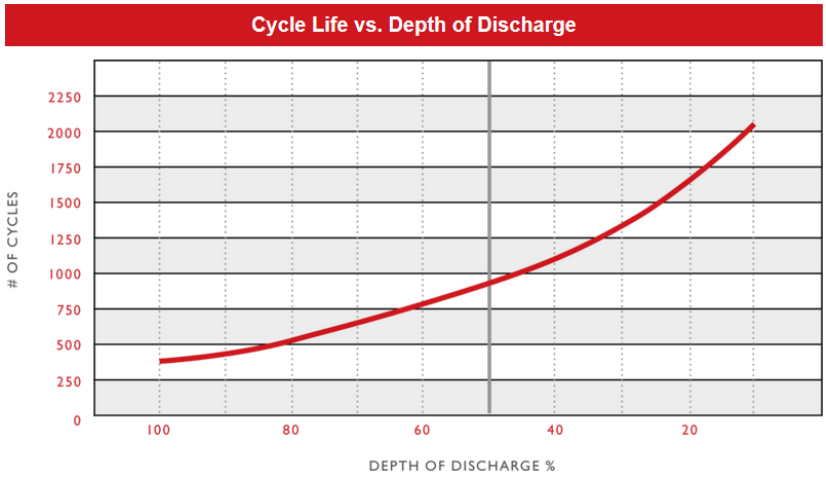

Figure 16. Cycle life of the battery vs. Depth of discharge (Rolls battery engineering, 2020)

The line graph illustrated the percentage of available capacity over ambient temperature. The working capacity is 100 at 25-degree Celsius and at least 40 during -30 degrees Celsius (Figure 17).

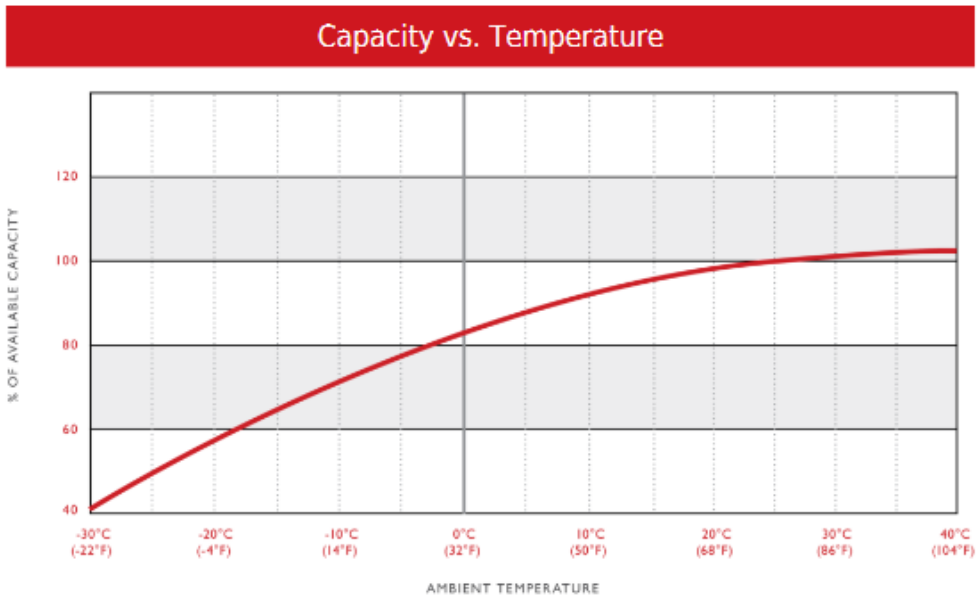

Figure 17. Capacity vs. Temperature (Rolls battery engineering, 2020)

4.5 Inverter

1000W pure sine wave AC power inverter 12V battery to 24V mains electricity used in the model (Figure 18). It converts 12V DC into 240V AC. It is used for any kind of electrical appliances that need the power of 240V. It is suitable for the battery and wire combination to get alternative current from solar and wind energy (Amazon.co.Uk, 2020).

The specific technical parameters of the inverter (Amazon.co.Uk, 2020).

Net weight	3.52 kg
Dimension (L x W x H) (cm)	37 x 25.4 x 12.2

An inverter was designed with length 11.4cm, width 21.33cm, and 6.55cm (Figure 18).

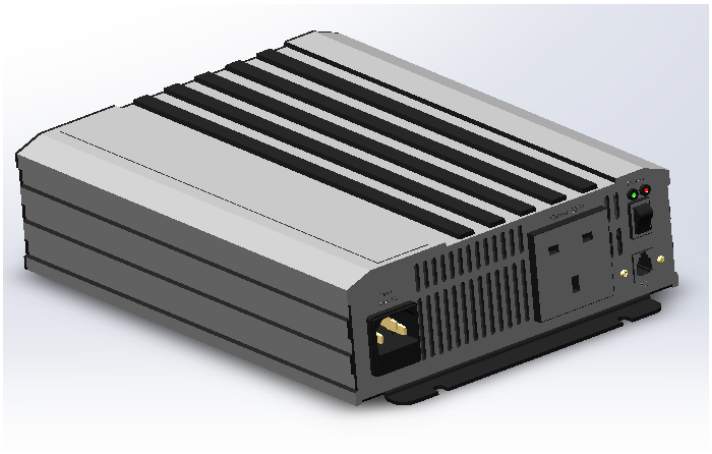

Figure 18. 3D model of Inverter

4.6 3 – Section of telescopic poles

The pole for a wind turbine is telescopic, and retractable or extendable, and it is 2890 mm tall in full form, but it can be adjusted according to need (Figure 19). The pole is attached to the trailer floor with 8 M12 Hexagon bolts, and its lower diameter is 300mm, narrowing to 100mm at the top. It is retracted down during the transfer. The wind turbine is attached to the top of the pole. The pole measurement was not too critical. The vertical wind turbine attached to the top of the section and the large bottom of the pole attached to the trailer.

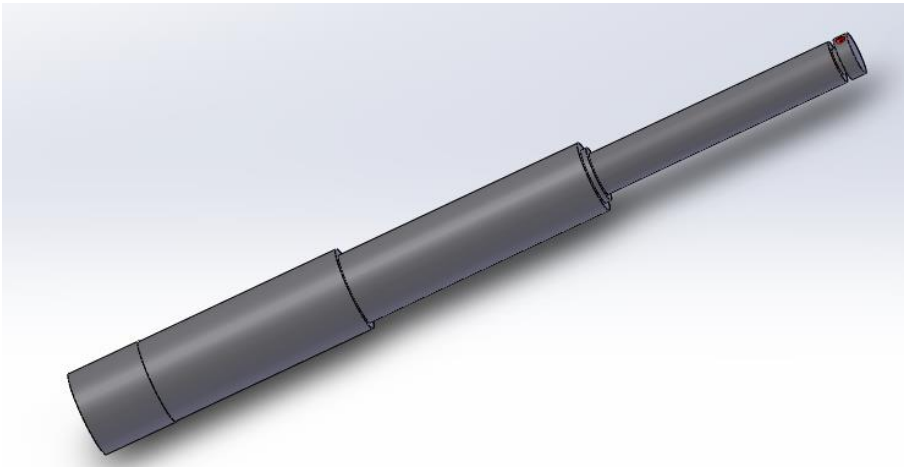

Figure 19. 3D model of 3 sections telescopic pole

4.7 Trailer

The trailer measurement for the model is 4250mm X 1850mm, with adjustable stands in each corner of the trailer to keep it from tilting (Figure 20). The trailer capacity is 750kg. It can carry four solar panels in the four corners of a trailer with a wind turbine in the center, four batteries, and an inverter. The trailer is the typical size of 1220Kg capacity (Findit.fi,

2020). The trailer and electrics are covered with a plastic cover, leaving the wind turbine and solar panel outside and visible.

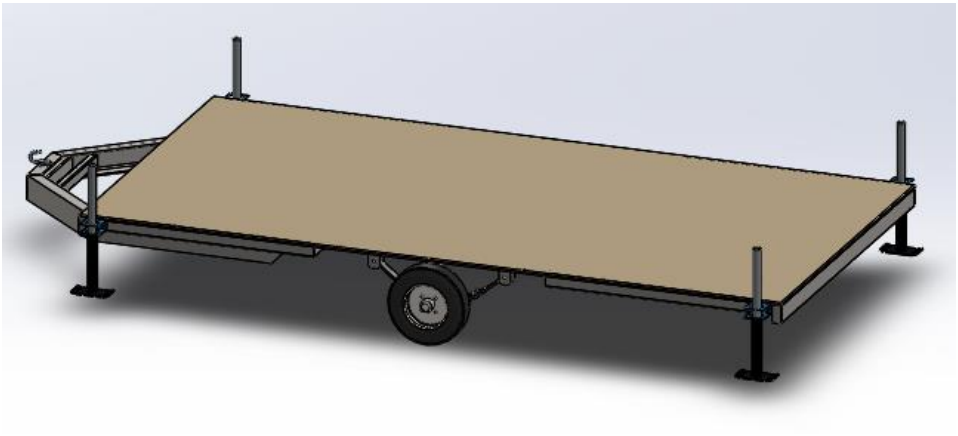

Figure 20. 3D model of trailer

4.8 Final model after combination

The trailer carries a series of solar panels, a vertical wind turbine attached with a telescopic pole, a charge controller, battery, and inverter. The solar panels are attached to the base which can rotate solar panel 360^0 and vertically 90^0 automatically according to the sun`s position to get more energy. The pole can be extended up to 3000mm.

The wind turbine pole can extend during the windy time or solar panels can rotate according to sunlight (Figure 21).

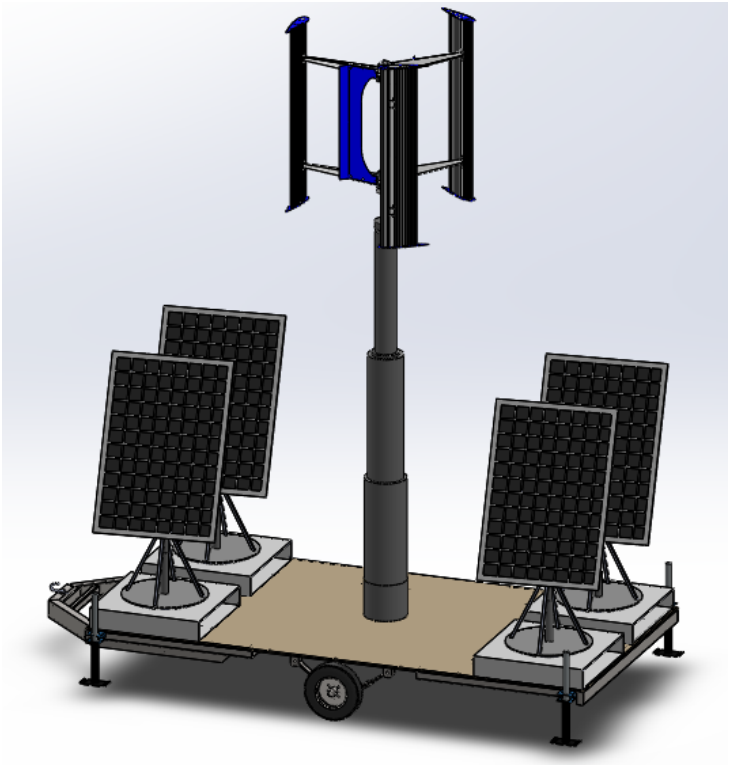

Figure 21. 3D model of a hybrid power system with extended pole

The wind turbine´s pole size can retract, and solar panels can be placed vertically during transportation (Figure 22).

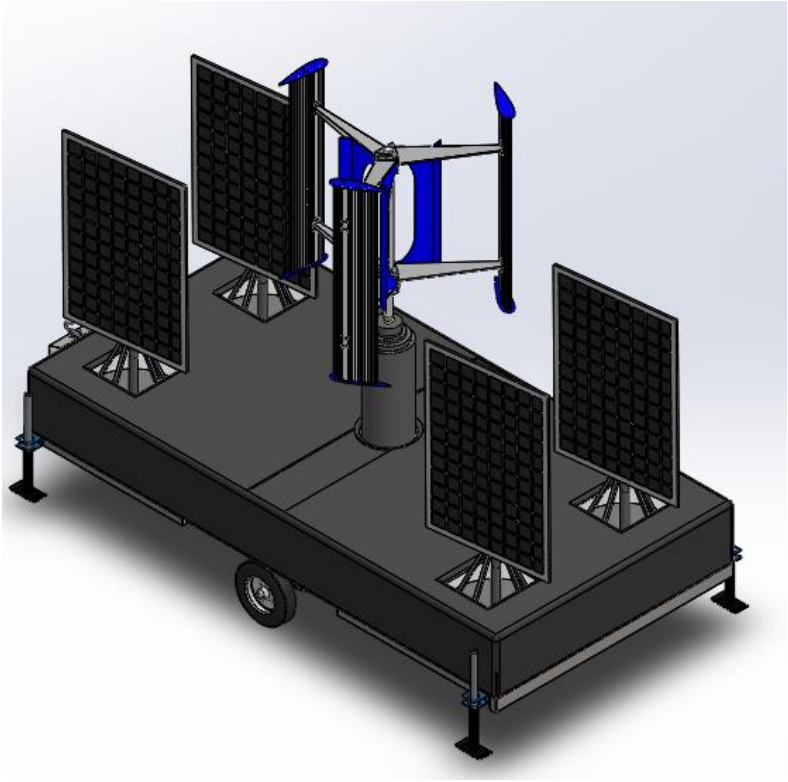

Figure 22. 3D model of a complete model of a hybrid power system with a retracted pole

5 CALCULATING ENERGY OUTPUT

The sunlight and wind speed always depend upon the site and weather. So, the generated power from four solar panels and a wind turbine determined from the following ways,

If the availability of the sun is of 5 hours per day,

Here, 4 solar panels of 500 watts are being used.

It means 4 x 500W = 2000W

energy output = Solar panel (watts) x sunlight average hours x 75%

= 2000 x 5 x 75% = 7500Whrs

We know that 1 unit is 1 KWhr

2kW solar panels will generate 7.5 to 5 units(kWh) per 5hrs.

Also, wind turbine energy output,

Rotor swept area, (A) = d x h

= 2 x 2.8

= $5.6m^2$

If the average wind speed is 4 m/s.

Available power in the wind (P_{avail}) = $0.5 \times \rho \times A \times v^3 \times C_P$

= $0.5 \times 1.2kg/m^3 \times 5.6\ m^2 \times (4\ m/s)^3 \times 59\%$

=126.8736W

If the wind always blows at the same speed, the power is always the same.

In case of the wind blows perfectly steady at 4 m/s for the entire 2 hours.

= 2 x 126.8736W = 253.7472W

The hybrid power system losses energy due to an inverter, battery, AC & DC cables, snow, dust, and temperature.

Again, The energy storage in battery calculation,

12-volt 6 cells AGM battery,

Battery watt-hours = Volts x Amp-hours

Battery watt-hours = 12 Volts x 200 Amp-hours

= 2400

Around 30 to 40% discharge rate, so the amount of usable energy in the battery gets from the following way.

Usable watt-hours = 0.6 X Battery watt-hours

Usable watt-hours = 1440 watt-hours

Therefore, one battery can store 1440 watt-hours usable energy.

6 ESTIMATED COST OF MODEL

Price of one solar panel = 275€ (Todoensolar, 2020)
4 x solar panels = 4 x 275€
= 1100€

Price of one wind turbine = 1010€ ($1,099.90 - Amazon.com, 2020)

Price of charge controller = 368.50€ ($399.95 - MWands, 2020).

Price of cable (50 feet Red & 50 feet Black Stranded Copper Clad Aluminum Wire in 18 AWG)

= 6.52€ ($9.95 - Amazon, 2020)

Price of four batteries = 4 x 401.61€ (£ 349.99 - Tayna batteries, 2020)
= 1606.44€

Price of an inverter = 114.45€ (£ 99.90 - Amazon.co.Uk, 2020)

Price of a trailer = 3 400 € (Findit.fi, 2020)

The total price = 8007.52€

The total model price is around 8007.52€with all the chosen equipment.

The estimated cost for the portable hybrid power system is calculated based on the market value of each equipment. Hence, the power system is not so costly and is a one-time investment.

7 CONCLUSION

This study aimed to design the 3D model of an easily transportable hybrid power system that joins a solar system with a wind system. It provides a reasonable solution for the electricity crisis and is made by analyzing and studying the components for making a model with energy storage.

The model can generate electricity, store it, and convert for AC use but electricity generation depends upon the weather on the site of installation. Solar panels can generate better electricity in summer than winter where a wind turbine works better in a windy place.

The model is in a trailer so that it can be transferred from one place to another place. The three distinct sections of the design; solar panels, a wind turbine, and electrical components which include a hybrid charge controller, an inverter, cables, and batteries. The plastic cover is used on the surface of the trailer for batteries and an inverter to protect them from bad weather, but solar panels and a wind turbine are outside and visible.

The solar panels and a wind turbine are energy generating devices that are mainly responsible for renewable sources use and can meet the basic energy needs. It is cost-effective and is a useful solution to provide energy to the electric applicants compared to the pure solar system and wind system. The energy stored in batteries assures the flow and provide of the required power in the night-time.

The estimated cost for the total model is around 8007.52€ with suitable equipment and the estimated weight is around 1220kg. The equipment can be replaced with aluminum alloys to make it lighter, however, it can increase the price.

The main advantage of the model is it can generate electricity in the presence of the sun as well as wind and can be easily transported with the help of a trailer. The model is useful for summer cottages, social activities like camping, outdoor programs, and natural disasters like floods, earthquakes, etc. The main disadvantage of the model is its weight due to which it needs a trailer for transportability. Likewise, the limitation of the system is that in case of continuous rain, there might not be any energy production. Therefore, investment in the development of a renewable sources-based power system to overcome the energy shortage issues which indicates that less fuel usage. Also, it is an ideal solution with sustainable and renewable energy for electricity problems.

8 REFERENCES

Aeolos wind turbine. 2020. [Electronic file]. [Accessed 25-03-2020]. Available: https://www.windturbinestar.com/1kwv-v-aeolos-wind-turbine.html

Amazon. 2020. [Electronic file]. [Accessed 05-04-2020]. Available: https://www.amazon.com/MAKEMU-Energy-Vertical-Generator-Domestic/dp/B00JP7U1AI

Amazon.com. 2020. [Electronic file]. [Accessed 05-04-2020]. Available: https://www.amazon.com/American-Gauge-Primary-Black-Available/dp/B07D74RGVM?th=1

Amazon.co.Uk. 2020. [Electronic file]. [Accessed 05-04-2020]. Available: https://www.amazon.co.uk/1000W-power-inverter-battery-electricity/dp/B017DSF1QE

American Wind Energy Association (AWEA). 2020. [Electronic file]. [Accessed 15-03-2020]. Available: https://www.awea.org/wind-101/basics-of-wind-energy

Ashish S. Ingole, Prof. Bhushan S., and Rakhonde. 2015. `Hybrid Power Generation System Using Wind Energy and Solar Energy´, International Journal of Scientific and Research Publications, vol. 5, pp. 1-3.

Britannica. 2020. [Electronic file]. [Accessed 05-03-2020]. Available: https://www.britannica.com/science/solar-energy

Chetan Sonawane, Manav Velani, Akash Singh, and Vikaskumar Tripathi. 2017. `Hybrid Power Generation System Using Vertical Axis Wind Turbine and Solar Panel`, International Journal of Advanced Research (IJAR), vol. 5, no. 3, pp. 2250-3153. [Accessed 05-03-2020]. Available: http://dx.doi.org/10.21474/IJAR01/3792

Energy-sage. 2020. Types of solar panels. [Electronic file]. [Accessed 16-03-2020]. Available: https://www.energysage.com/solar/101/types-solar-panels/

Findit.fi. 2020. [Electronic file]. [Accessed 05-04-2020]. Available: https://www.findit.fi/sv/1506288.htm

Freedom Solar Power. 2018. 7 use of solar energy. [Accessed 05-03-2020]. Available: https://freedomsolarpower.com/blog/7-uses-of-solar-energy

GreensunSolar. 2020. [Electronic file]. [Accessed 25-03-2020]. Available: https://www.greensunpv.com/greensun-mono-48v-solar-panel-480w-490w-500w_p26.html

I.A. Adejumobi, S.G. Oyagbinrin, F. G. Akinboro, and M.B. Olajide. 2011. `Hybrid Solar and Wind Power: An Essential for Information Communication Technology Infrastructure and People in Rural Communication, IJRRAS, vol. 9, pp 130-138. [Accessed 08-03-2020]. Available: https://core.ac.uk/download/pdf/25716356.pdf

J. Fadil, Soedibyo, and M. Ashari. 2017. ´Performance analysis of vertical axis wind turbine with variable swept area´, International Seminar on Intelligent Technology and Its Applications (ISITIA), pp. 217-221. [Accessed 21-03-2020]. Available: 10.1109/ISITIA.2017.8124083.

Jim Doucet, Dan Eggleston, and Jeremy Shaw. 2006-7. DC/AC Pure Sine Wave Inverter, pp. 05-06. [Accessed 25-03-2020]. Available: https://web.wpi.edu/Pubs/E-project/Available/E-project-042507-092653/unrestricted/MQP_D_1_2.pdf

L Ragunath & Santhakumar, Senthilvel, and Ilamathi, Dr. 2016. `Hybrid Energy Generation Through Vertical Axis Savonius Wind Turbine and Solar Panel´, International Journal for Innovative Research in Science & Technology, vol. 2, pp. 304-311.

Mergu Chandramouly and Dr. A. Raghuram. 2017. `Introduction to Solar Wind Hybrid Energy Systems´, International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE), Vol 3, Issue 12, pp. 1-6. [Accessed 25-03-2020]. Available: https://www.technoarete.org/common_abstract/pdf/IJEREEE/v4/i12/Ext_28307.pdf

National Geography, 2020. [Accessed 06-03-2020]. Available: https://www.nationalgeographic.com/environment/global-warming/wind-power/

National Geography, 2020. [Accessed 10-03-2020]. Available: https://www.nationalgeographic.org/article/putting-wind-work/

National Geographic (resource library), 2020. [Accessed 01-03-2020]. Available: https://www.nationalgeographic.org/encyclopedia/renewable-resources/

Our World in Data, 2019. [Accessed 01-03-2020]. Available: https://ourworldindata.org/renewable-energy

Rolls battery engineering. 2020. [Electronic file]. [Accessed 05-04-2020]. Available: https://rollsbattery.com/wp-content/uploads/batteries/R12-200AGM.pdf

Rolls battery engineering. 2020. [Electronic file]. [Accessed 05-04-2020]. Available: https://www.rollsbattery.com/battery/r12-200agm/

Renewable Solar Energy. 2020. Hybrid Renewable Energy. [Electronic file]. [Accessed 16-03-2020]. Available: http://renewable-solarenergy.com/hybrid-renewable-energy.html

Roux, Jeremie, Martin, and Gerard, 2010. Wind Turbines: Types, Economics, and Development. New York: Nova Science Publishers, pp.9-14

RexCo Technology. 2020. [Electronic file]. [Accessed 21-03-2020]. Available: http://www.bestwindsolar.com/product/RC-HV-70.html

S. Ashok. 2020. Solar energy. [Accessed 05-03-2020]. Available: https://www.britannica.com/science/solar-energy

S.C. Bhatia and R.K. Gupta. 2018. Textbook of Renewable Energy. New Delhi: Woodhead Publishing India PVT. Ltd.

Shalini S. Durgam, Anuradha B. Musale, Sneha A. Balki, Payal S. Gahane, & Asst. Prof. L. B. Awale, March 2015. Ac Hybrid Charge Controller, vol. 5, no. 3, (Part -5), pp. 05-10. [Electronic file]. [Accessed 21-03-2020]. Available: https://www.ijera.com/papers/Vol5_issue3/Part%20-%205/B503050510.pdf

SOLARQUOTES. 2020. Polycrystalline Solar Panels. [Electronic file]. [Accessed 18-03-2020]. Available: https://www.solarquotes.com.au/panels/photovoltaic/polycrystalline/

Sumit Wagh, and Dr. P.V.Walke. 2017. `Review on Wind-Solar Hybrid Power System´, International Journal of Research in Science & Engineering, vol. 3, no. 2, pp. 71-76.

Tayna batteries. 2020. [Electronic file]. [Accessed 05-04-2020]. Available: https://www.tayna.co.uk/leisure-batteries/rolls/r12-200-agm/

Team Product Line. 2019. Monocrystalline solar panel: Solar cells that have longevity for up to 30 years. India Times (economic times). [Electronic file]. [Accessed 18-03-2020]. Available: https://economictimes.indiatimes.com/small-biz/productline/power-generation/monocrystalline-solar-panel-solar-cells-that-have-longevity-up-to-30-years/articleshow/69140542.cms?from=mdr

The Walden Effect. 2012. [Electronic file]. [Accessed 25-03-2020]. Available: http://www.waldeneffect.org/blog/How_many_batteries_do_I_need_for_my_solar_panels__63__/

Todoensolar. 2020. [Electronic file]. [Accessed 05-04-2020]. Available: https://www.todoensolar.com/solar-panel-500w-24v-96-cells

Windynation. 2010. [Electronic file]. [Accessed 05-04-2020]. Available: https://www.windynation.com/cm/articles_choosing-right-wire-size.pdf

Vivint Solar. 2020. How to Measure Solar Panel Output. [Electronic file]. [Accessed 20-03-2020]. Available: https://www.vivintsolar.com/learning-center/how-calculate-solar-panel-output

YellowLite. 2020. Harvesting Clean Energy. [Accessed 05-03-2020]. Available: https://www.yellowlite.com/blog/post/the-difference-between-active-and-passive-solar-systems/

Zeyu Dinga, Hongjuan Houa, Gang Yua, Eric Hub, Liqiang Duana, and Jin Zhaoc. 2019. `Performance analysis of a wind-solar hybrid power generation system´, Energy Conversion and Management, vol. 3, pp. 223-234 Available: https://doi.org/10.1016/j.enconman.2018.11.080

12 Volt Planet Ltd. 2020. [Electronic file]. [Accessed 05-04-2020]. Available: https://www.12voltplanet.co.uk/cable-sizing-selection.html